DISSOLUTION KINETICS OF TOLUENE POOLS IN SATURATED POROUS MEDIA

Moon - Full Yeh and Evangelos A. Voudrias

AUTHOR: Georgia Institute of Technology, 26157 Georgia Tech Station, Atlanta, Georgia 30332.
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INTRODUCTION

Non-aqueous phase liquids (NAPLs) are liquids immiscible with water and may consist of single components, such as toluene, or mixtures of a large number of components, such as gasoline and aviation fuel. In recent years, groundwater contamination by NAPLs has reached significant proportions. Every state in the United States, Georgia included, has reported NAPL contamination problems due to leaking underground storage tanks (USTs), ruptured pipelines, surface spills, hazardous landfills, and disposal sites. Although the NAPL solubility is generally low (a few hundred to a few thousand mg.L), it is frequently several orders of magnitude higher than the maximum contaminant level for drinking water. Therefore, a small amount of NAPL may contaminate a large volume of groundwater (Mackay and Cherry, 1989; Anderson et al., 1992).

A common approach for remediating contaminated groundwater is to "pump-and-treat" the groundwater at the surface of the ground. The effectiveness of this method is limited by the rate at which NAPL components are dissolved into groundwater. The effectiveness of this method is limited by the rate at which NAPL components are dissolved into groundwater. The rate of biodegradation of NAPLs in groundwater depends on the concentrations of oxygen and nutrients and the availability of dissolved dissolution kinetics of the NAPL. The objective of this work was to study the dissolution kinetics of toluene pools floating at the capillary fringe, above the water table in a two-dimensional experimental aquifer.

MATERIAL AND METHODS

Toluene pools, approximately 60-cm long, 20-cm wide, and 3-cm thick, were formed by applying two liters of toluene containing one gram per liter of Oil-Red EGN dye above the water table in a two-dimensional aquifer, 100-cm long by 50-cm wide by 20-cm wide (Figure 1). Medium sand, with particle sizes between 0.8 mm and 0.5 mm, was used as the porous medium in all experiments. Tap water was used in all experiments to simulate groundwater. All experiments were conducted within a 20°C constant temperature room.

Pore water velocities between 10 cm/day and 100 cm/day were used. Sampling ports were located in one of the side glass walls of the experimental aquifer. Groundwater samples were taken using 4-inch long, 18-gauge stainless steel needles, which were inserted into the ports and pushed into the porous medium. Interstitial water samples were withdrawn from selected sampling ports of the aquifer with a one milliliter gastight syringe (model #1005, Hamilton Company, Reno, NV). The samples were analyzed by the purge-and-trap procedure using a 4460A Sample Concentrator (O.I. Corporation) and a Hewlett-Packard Gas Chromatograph (Model 5710A) equipped with a flame ionization detector.

RESULTS AND DISCUSSION

The evolution of toluene concentration with time at sampling port P-9, which was located at the downstream end of the pool and at a distance 4-cm below the pool surface, shown in Figure 2. The results indicate that the dissolution of the toluene pool required approximately 100 hours to reach steady-state at 57.2-cm/day pore velocity. The highest toluene concentration detected at sampling port P-9 was 24 mg/L, which is approximately 5 percent of the toluene solubility of 515 mg/L at 20°C (Verschueren, 1983). Dissolved toluene concentrations increased with increasing distance along the pool. Figure 3 presents the steady-state concentration versus distance profile for the sampling ports located 4-cm below the pool surface.

As the vertical distance from the pool increased, concentration levels decreased sharply, resulting in a relatively thin plume of dissolved toluene. For example, the steady-state concentration in port P-10 (Figure 1) was 0.03 mg/L. This was 800-times lower than that detected at P-9 (24 mg/L) which was located only 4-cm above P-10. Within 8 cm of vertical distance from the pool surface, the dissolved toluene concentration decreased from solubility (515 mg/L) to 0.03 mg/L at P-10, i.e. a decrease by 99.994 percent. Figure 3 also illustrates the effect of vertical distance from the pool on dissolved toluene concentrations under steady-state conditions.

The above data suggest that cleanup of NAPL-

contaminated groundwater by "pump-and-treat" methods may be ineffective and an extremely long process, producing massive volumes of dilute waste streams. This occurs because NAPL dissolution kinetics result in low dissolved NAPL concentrations on absolute scale, although these concentreations may be high relative to drinking water standards.

One of the factors affecting in-situ biological treatment of NAPL-contaminated groundwater is the rate at which NAPL components are dissolved in groundwater. However, the rate of biodegredation may be limited by low dissolved NAPL concentrations, even when oxygen and nutrients are abundant. Development of a reliable approach for in-situ biorestoration will require an accurate description of the NAPL dissolution process.

ACKNOWLEDGEMENT

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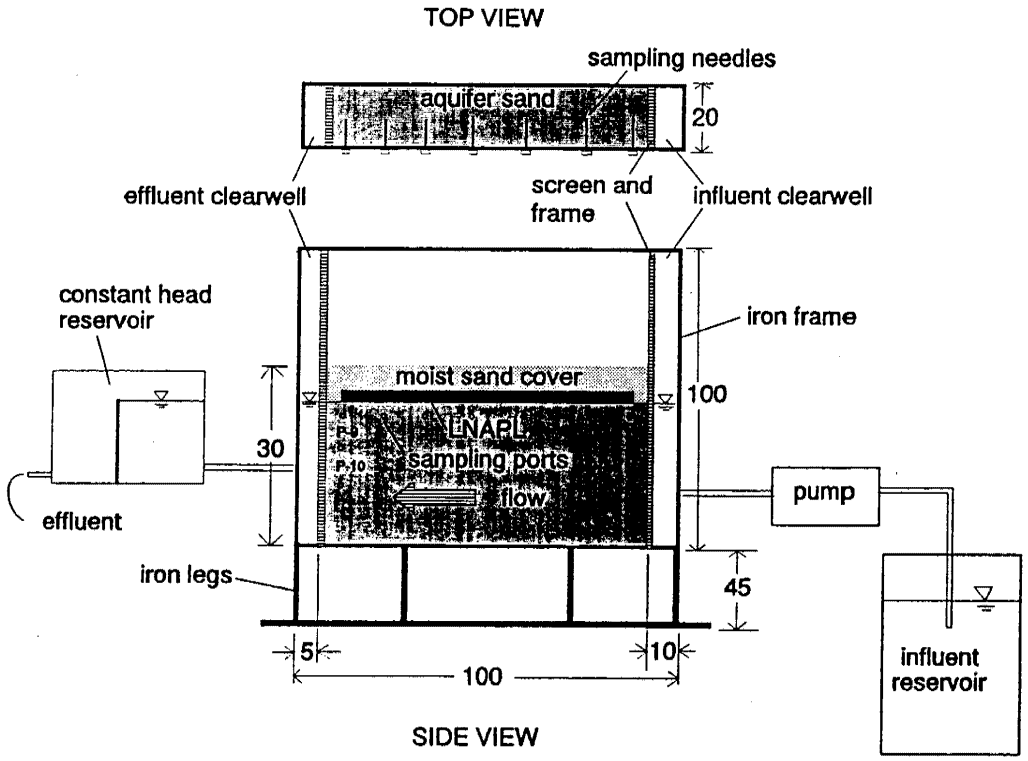

Figure 1. Schematic diagram of experimental aquifer and tank assembly with influent and effluent appurtenances.

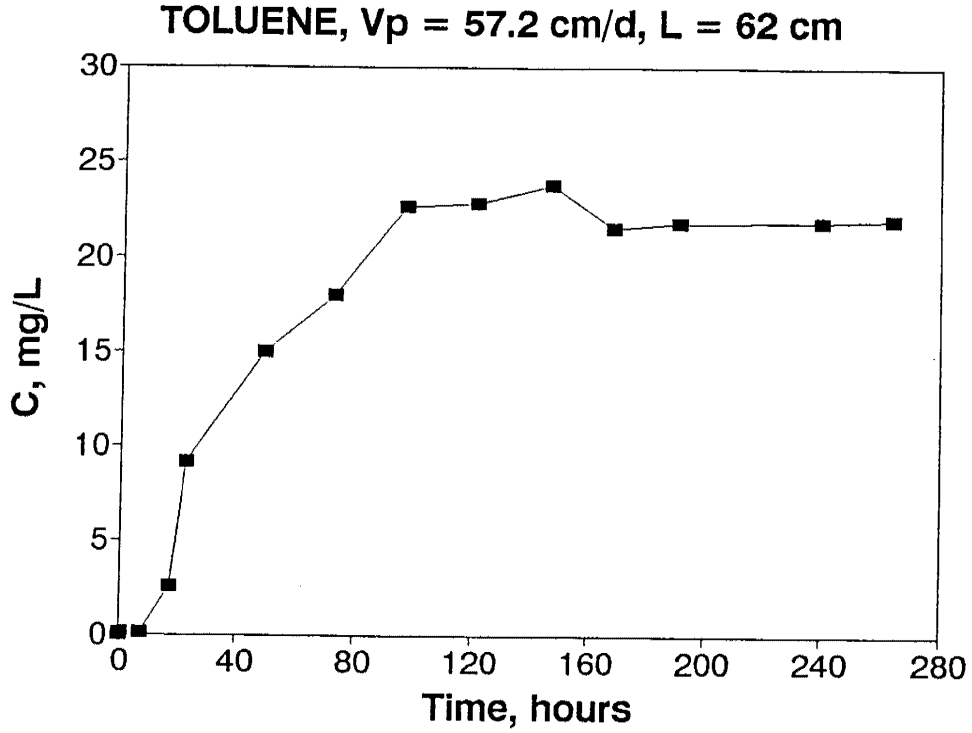

Figure 2. Concentration of dissolved toluene vs. experimental time.

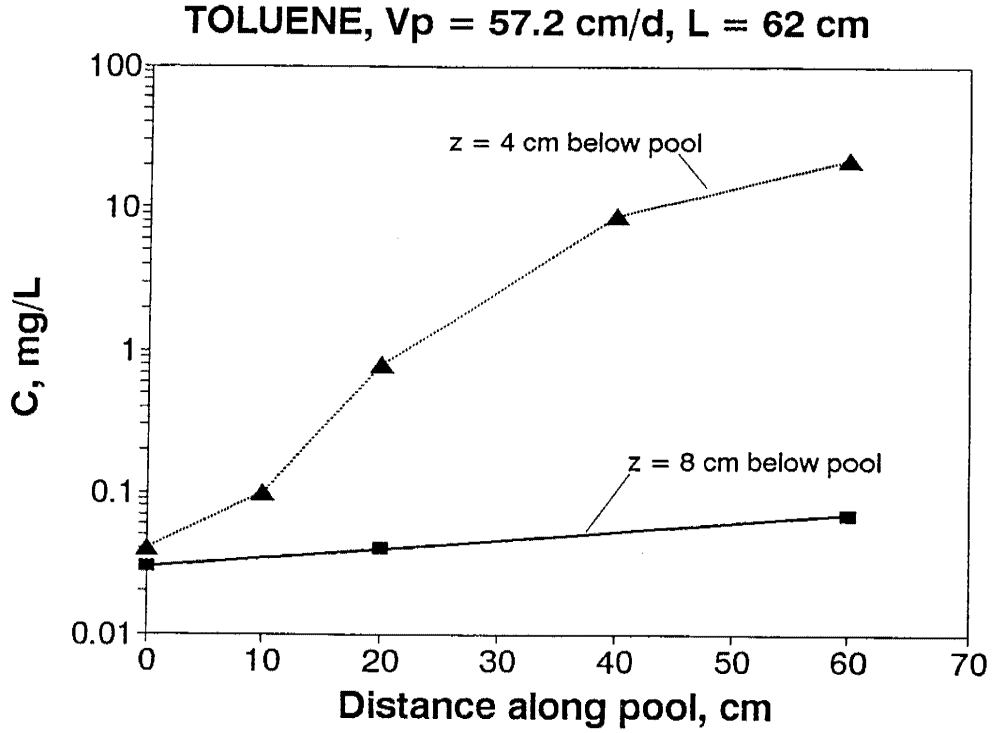

Figure 3. Steady-state concentration profile vs. distance along the pool for sampling ports located at distances 4 and 8 cm below the pool.